CLAIMS

What is claimed is:

1. A method of determining a parameter value for a set of calibration standards used to calibrate a multiport vector network analyzer, the method comprising:

employing measurements of an asymmetric reciprocal device made with the multiport vector network analyzer to optimize a parameter value of a defining parameter of the set of calibration standards.

2. The method of Claim 1, wherein the asymmetric reciprocal device has a number of ports greater than or equal to a number of test ports of the multiport vector network analyzer.

3. The method of determining of Claim 1, wherein the optimized parameter value minimizes a difference between a set of corrected forward transmission S-parameters and a corresponding set of corrected reverse transmission S-parameters, the difference being computed from the employed measurements of the asymmetric reciprocal device.

4. The method of determining of Claim 3, wherein computing the set of corrected forward transmission S-parameters and the corresponding set of reverse transmission S-parameters comprises using the parameter value being optimized; using measurements of the set of calibrations standards; and using an error model of the multiport vector network analyzer.

5. The method of determining of Claim 1, wherein employing comprises:

measuring S-parameters of the set of calibration standards;

measuring raw S-parameters of the asymmetric reciprocal device; and

adjusting the parameter value to minimize a difference between a set of corrected forward transmission S-parameters and a corresponding set of corrected reverse transmission S-parameters of the asymmetric reciprocal device.

6. The method of determining of Claim 5, wherein the set of corrected forward transmission S-parameters and the corresponding set of reverse transmission S-parameters are computed from the measured raw S-parameters of the asymmetric reciprocal device using an error correction, coefficients of the error correction being computed from the measured S-parameters of the set of calibration standards and the parameter value being adjusted, and wherein the optimized parameter value is the adjusted parameter value when the difference is minimized.

7. The method of determining of Claim 5, wherein parameter values for a plurality of defining parameters are optimized and the S-parameters are measured at a plurality of frequencies.

8. The method of determining of Claim 1, wherein defining parameters of at least one of standards of the set of calibration standards are known.

9. The method of determining of Claim 1, wherein defining parameters of a single *thru* standard of the set of calibration standards are known.

10. A method of determining a parameter value of a calibration standard in a set of calibration standards used to calibrate a multiport vector network analyzer having more than two test ports, the method comprising:

measuring S-parameters of the set of calibration standards using the multiport vector network analyzer;

measuring raw S-parameters for an asymmetric reciprocal device using the multiport vector network analyzer; and

adjusting the parameter value of the calibration standard until a difference between a set of corrected forward transmission S-parameters and a corresponding set of corrected reverse transmission S-parameters for the asymmetric reciprocal device is minimized.

11. The method of determining of Claim 10, wherein the asymmetric reciprocal device has more than two ports.

12. The method of determining of Claim 10, wherein the measured S-parameters of the set of calibration standards and with the parameter value are employed to compute error coefficients of an error model for the multiport vector network analyzer, the computed error coefficients being employed to compute the set of corrected forward transmission S-parameters and the corresponding set of corrected reverse transmission S-parameters from the measured raw S-parameters.

13. The method of determining of Claim 10, wherein adjusting the parameter value comprises iteratively adjusting to minimize the difference.

14. The method of determining of Claim 10, wherein adjusting the parameter value comprises:

selecting a value for the parameter value being adjusted;

computing a set of error coefficients of an error model of the multiport vector network analyzer from the measured S-parameters of the set of calibration standards and using the selected value;

applying an error correction to a set of raw forward transmission S-parameters and a corresponding set of raw reverse transmission S-parameters measured for the asymmetric reciprocal device to produce the corrected forward transmission S-parameter and the corrected reverse transmission S-parameter; and

determining the difference between the set of corrected forward transmission S-parameters and the corresponding set of corrected reverse transmission S-parameters.

15. The method of determining of Claim 14, wherein determining the difference comprises computing a metric M given by

$$M = \sum_{f} |S_{nm} - S_{mn}|^2$$

where S_{nm} is the set of forward transmission S-parameter values, S_{mn} is the corresponding set of reverse transmission S-parameter values, , and f is a frequency value.

16. The method of determining of Claim 10, further comprising one or both of reporting a set of optimized parameter values for the set of calibration standards and storing a set of error coefficients of an error model for the multiport vector network analyzer, wherein the optimized set includes the adjusted parameter value, and wherein the set of error coefficients is computed from the measured S-parameters of the set of calibration standards and the adjusted parameter value.

17. The method of determining of Claim 10, further comprising:

performing calibrated measurements on a multiport device under test with the multport vector network analyzer using the set of calibration standards and the adjusted parameter value.

18. A method of compensating a calibration of a multiport vector network analyzer having more than two test ports, the method comprising:

optimizing error coefficients of an error model of the multiport vector network analyzer using measurements of an asymmetric reciprocal device,

wherein the calibration is compensated to minimize effects of a poorly known defining parameter of a set of calibration standards used for the calibration.

19. The method of compensating of Claim 18, wherein one or both of the asymmetric reciprocal device is a multiport device having more than two ports and a *thru* standard of the set of calibration standards is a precision *thru* standard.

20. The method of compensating of Claim 18, wherein optimizing comprises:

measuring S-parameters of the set of calibration standards using the multiport vector network analyzer;

measuring raw S-parameters for the asymmetric reciprocal device using the multiport vector network analyzer;

adjusting a parameter value of the defining parameter to minimize a difference between a set of corrected forward transmission S-parameters and a corresponding set of corrected reverse transmission S-parameters for the asymmetric reciprocal device; and

storing a set of the error coefficients for the error model, the error coefficient set being extracted from an optimized set of parameter values, the optimized set including the adjusted parameter value of the defining parameter.

21. The method of compensating of Claim 20, wherein adjusting a parameter value comprises iteratively adjusting the parameter value until a minimization goal for the difference is achieved.

22. The method of compensating of Claim 20, wherein adjusting a parameter value comprises:

selecting a value of the parameter value being adjusted;

computing the set of error coefficients of the error model of the multiport vector network analyzer from the measured S-parameters of the set of calibration standards and the selected value;

applying an error correction to a set of raw forward transmission S-parameters and a corresponding set of raw reverse transmission S-parameters measured for the asymmetric reciprocal device to produce the set of corrected forward transmission S-parameters and the corresponding set of corrected reverse transmission S-parameters; and

determining the difference between the set of corrected forward transmission S-parameters and the corresponding set of corrected reverse transmission S-parameters.

23. The method of compensating of Claim 18, further comprising:

performing calibrated measurements on a multiport device under test with the multiport vector network analyzer using the optimized error coefficients.

24. A method of compensating a calibration of a multiport vector network analyzer having more than two ports, the method comprising:

measuring S-parameters of a set of calibration standards using the multiport vector network analyzer;

measuring raw S-parameters for an asymmetric reciprocal device using the multiport vector network analyzer; and

adjusting a parameter value of the set of calibration standards to minimize a difference between corrected forward transmission S-parameters and corresponding corrected reverse transmission S-parameters for the asymmetric reciprocal device.

25. The method of compensating of Claim 24, wherein defining parameters of a single *thru* standard of the set of calibration standards are known.

26. The method of compensating of Claim 24, further comprising one or more of:

storing a set of error coefficients for an error model, the error coefficient set being extracted from an optimized set of parameter values, the optimized set including the adjusted parameter value of the set of calibration standards;

reporting a set of optimized parameter values for the set of calibration standards, the optimized set including the adjusted parameter value; and

measuring the S-parameters at a plurality of frequencies.

27. The method of compensating of Claim 24, wherein adjusting a parameter value comprises:

selecting a value of the parameter value being adjusted;

computing a set of error coefficients for an error model of the multiport vector network analyzer from the measured S-parameters of the set of calibration standards and the selected value;

applying an error correction to a set of raw forward transmission S-parameters and a corresponding set of raw reverse transmission S-parameters measured for the asymmetric reciprocal device to produce the corrected forward transmission S-parameters and the corresponding corrected reverse transmission S-parameters; and

determining the difference between the corrected forward transmission S-parameters and the corresponding corrected reverse transmission S-parameters.

28. A multiport vector network analyzer comprising:

a calibration compensator that compensates for inaccuracies in knowledge of a parameter value of a calibration standard in a set of calibration standards, the set of calibration standards being used to calibrate the multiport vector network analyzer,

the calibration compensator comprising a measurement of an asymmetric reciprocal device, the multiport vector network analyzer having more than two ports.

29. A multiport vector network analyzer that compensates for inaccuracies in knowledge of a parameter value of a set of calibration standards, the analyzer comprising:

a computer program stored in a computer readable medium;

wherein the computer program comprises instruction that implement compensating a calibration of the multiport vector network analyzer using measurements of an asymmetric reciprocal device to determine an optimized set of error coefficients for the set of calibration standards, the multiport vector analyzer having more than two ports.

30. The multiport vector network analyzer of Claim 29, further comprising:

a test set, the test set comprising the more than two ports, the ports being temporarily connected to a calibration standard of the set of calibration standards and independently temporarily connected to the asymmetric reciprocal device;

a memory that stores the computer program; and

a controller that controls an operation of the test set and executes the computer program.

31. The vector network analyzer of Claim 29, wherein the instructions of the computer program comprise:

instructions that implement measuring S-parameters of the set of calibration standards;

instructions that implement measuring raw S-parameters for the asymmetric reciprocal device;

instructions that implement adjusting the parameter value of the set of calibration standards to minimize a difference between a set of corrected forward transmission S-parameters and a corresponding set of corrected reverse transmission S-parameter for the asymmetric reciprocal device, the adjusted parameter value being used to compute the optimized set of error coefficients; and

instructions that implement storing the optimized set of error coefficients.

32. A calibration compensation system comprising:

a computer;

a multiport vector network analyzer having more than two ports; and

a computer program stored in a memory, the computer program being executed by the computer,

wherein the computer program comprises instructions that, when executed by the computer, implement determining a parameter value of a defining parameter of a calibration standard in a set of calibration standards using a measurement of an asymmetric reciprocal device.

33. The calibration compensation system of Claim 32, wherein the instructions of the computer program comprise:

instructions that implement measuring S-parameters for the set of calibration standards using the multiport vector network analyzer;

instructions that implement measuring raw S-parameters for the asymmetric reciprocal device using the multiport vector network analyzer;

instructions that implement adjusting the parameter value to minimize a difference between a set of corrected measured forward transmission S-parameters and a corresponding set of corrected reverse transmission S-parameters of the asymmetric reciprocal device; and

instructions that implement reporting an optimized parameter value, the optimized parameter value being the adjusted parameter value for the calibration standard.

34. The calibration compensation system of Claim 32, wherein the instructions of the computer program further comprises instructions that implement computing and storing an error coefficient for an error model used by the multiport vector network analyzer, the error coefficient being computed from an optimized parameter value for the defining parameter of the calibration standard.

35. The calibration system of Claim 33, wherein the set of calibration standards comprises a precision *thru* standard, the parameter value being adjusted being a value of a defining parameter for a standard of the set other than the precision *thru* standard.